N°17
SEPTEMBER
2012

ONEMA
MEETINGS

Research update on climate change and low-flow conditions in France

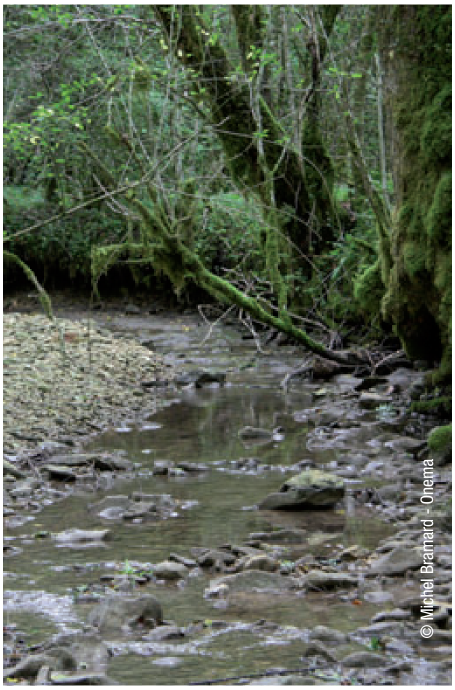
A forward-looking symposium on quantitative hydrology (19-20 March 2012)

A forward-looking meeting on quantitative hydrology was organised by Onema (national agency for water and aquatic environments) on 19 and 20 March in Paris. Approximately 20 past, current and future projects funded by Onema were presented. Scientists and water managers discussed the current directions taken by the quantitative hydrology research in France. The discussions addressed in depth the linked issues of climate change and the management of low-flow conditions, a major social and ecological issue. This document reports on progress in research and on the remaining issues.

With climate change upon us, the future of water resources is a source of increasing concern in both society and the scientific community. What consequences will the anticipated changes in atmospheric temperatures and precipitations have on the flow rates of rivers, the frequency and severity of low-flow conditions, and groundwater levels? Reliable predictions for quantitative hydrology are a key factor in understanding the major social and ecological issues linked to climate change. Considerable research is devoted to the topic in support of adaptation policies. In 2010 in France, the Ecology ministry launched the Explore 2070 forward-looking programme, which ended in October 2012, to develop a method combining hydrology with socio-economic and demographic projections to define adaptation strategies in response to the challenges raised by climate change for the management of water resources.

More severe low-flow conditions

The initial results of the Explore 2070 project, presented by X. de Lacaze during the Onema symposium, confirmed the very clear trends toward a warmer and drier climate in continental France. The project is based on the IPCC A1B scenario, considered a mid-range scenario[1], combined with a one-metre increase in sea level by 2070. The effects on water resources were calculated for over 100 river basins in France by regionalising the results of seven global climate models that were input into two hydrological models (GR4J and ISBA-MODCOU) to calculate hydrological impacts. The statistically robust results predict a general drop in mean annual flow rates by the middle of the century. Rates could drop by 20% in a majority of river basins and even more in the Adour-Garonne, Loire-Brittany and Seine-Normandy basins. Sharp changes are also expected in low-flow rates. The simulated monthly flow rates for August and QMNA5, the annual minimum monthly flow rate with a five-year return period, are projected to drop by 30 to 60% (± 20%) in the Saône and Rhône basins, in Seine-Normandy and



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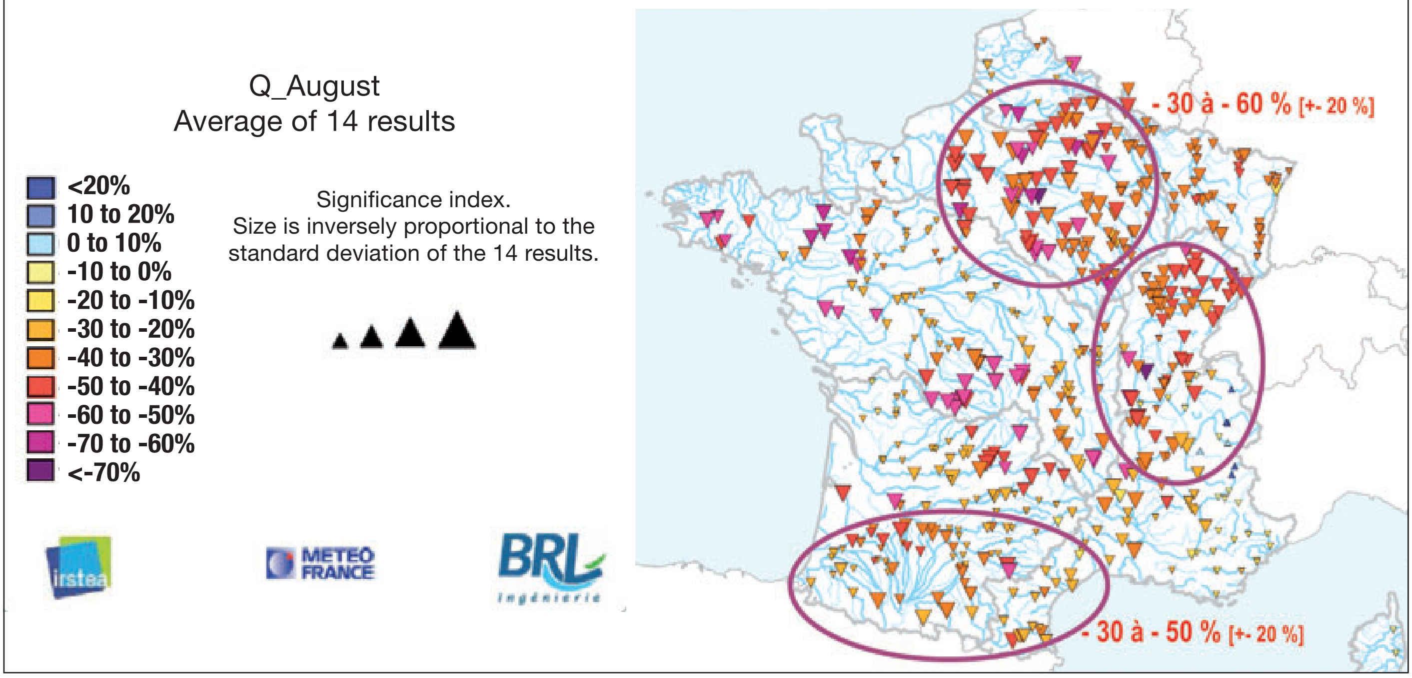
[1] Scenario drawn from the IPCC fourth assessment report (www.ipcc.ch).

in Adour-Garonne (Figure 1). These major shifts in surface hydrology would be accompanied by a general reduction in groundwater recharge, as well as an increase in water temperature. To better understand the links between climate and low-flow conditions, Irstea developed a statistical approach (presented by J.-Ph. Vidal) to complement the

Possible change between 1961-1990 and 2046-2065 in the annual minimum monthly flow rate (5-year return period)



hydrological models. Using data series spanning the period 1948-2008, the study attempted to detect correlations between the hydrological data from 220 French hydrological stations and various indicators of climate variability, e.g. the North-Atlantic oscillation (NAO), the Atlantic multidecadal oscillation (AMO) and the frequency of different weather patterns (WP) defined by Météo France. A number of important observations were made. On the annual time scale over single years, mean flow rates were, unsurprisingly, much lower during dry years (WP8) and higher during wet years (WP2). The study also revealed a clear link between the severity of low-flow rates and the NAO index values of the previous summer. Generally speaking, the «large-scale» indexes mentioned above showed better correlation with low-flow dates than time (calendar year). This opens up a number of possibilities. Trends in these indices could supply an additional factor in making hydrological projections. On the seasonal level, the correlations could also be used to predict and anticipate low-flow conditions.

Models and tools to improve management of low-flow conditions

In light of the above, it would appear essential to improve and harmonise the tools currently used to manage low-flow conditions on the national level. One goal is to have a map showing reference values for the interannual mean flow rate (QA, without anthropogenic influence) and QMNA5 for all rivers in France. That was the topic of a four-year project (presented by V. Andréassian) carried out jointly by Irstea teams in Aix, Antony and Lyon.
Each team mapped all the river sections contained in the Carthage[2] database using one of three methods, respectively the regionalised monthly rainfall-runoff model, a model using an average weighted by the distance between the estimation and measurement points and a kriging model. The three methods were adapted to produce continuous

Maïa Akopian,
Seine-Normandy water agency

Adaptation must take place on the local level

« In our region, we have already seen falling low-flow rates, notably in the up-stream areas of river basins. But it is difficult for an institution such as ours to set up an adaptation process because our operational cycles are much shorter than the periods over which climate change occurs. Identifying the causes of the changes, whether the climate or other pressures, remains a complex issue. Better understanding of the causes of low flows would enable us to take concrete measures, if needed, with other stakeholders in the field. To that end, the studies carried out on the national level on general trends should be complemented by more local studies on the responsible mechanisms. The links between regional stakeholders and Onema must be pursued over the long term via a durable network of participants. That is one of the conditions if we are to organise our specific programmes.»

[2] Database for the French hydrographic network.

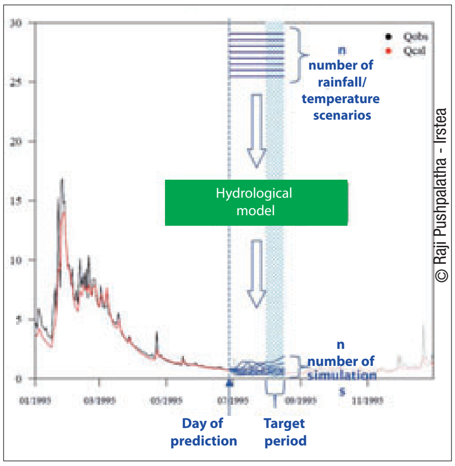


Figure 2. Theory behind the prediction of low flows using hydrological modelling (Premhyce).

Mapping and modelling temporary rivers in continental France

In a context of worsening low-flow conditions, locating and characterising temporary rivers, i.e. those that occasionally have no flow, has taken on increasing importance for water management. In France, they now represent over 20% of the total length of rivers in areas ranging well beyond the Mediterranean coast, according to a map drafted by Irstea following an in-depth analysis of the «zeros» in the Hydro database. The spatial and temporal distribution of these temporary rivers was modelled using 628 measurement stations identified as being only slightly subject to anthropogenic influences. The initial results (presented by P. Maugis) must still be improved, but they can already be used to simulate mean dry periods taking into account a number of predictive factors, e.g. minimum temperature, summer rainfall, chalky substrate and average slope of the river basin. The project was also a chance to test the relevance of water detectors in over 30 temporary rivers. The detectors turned out to be a worthwhile alternative to repeated observations for small rivers and those having a stable regime, but many were damaged on rivers with strong currents.

data that is consistent between the upstream and downstream sections. The methods were then combined by a Bayesian approach. The resulting maps display estimated QA and QMNA5 values, as well as high and low ranges. A column in the database is provided for each administrative service to fill in its own data if they are considered more accurate.

In parallel, work was carried out to predict low flows up to two months in advance. Forecasts of this type, which enable water stakeholders to manage difficult periods as best possible, are already available in France using various types of hydrological models. Since 2011 in the Premhyce project (Figure 2), five of the main models developed in France, e.g. Isba-Modcou (Météo France), Gardenia & Eros (BRGM), GR5j (Irstea), Mordor (EDF) and Présages (CEGUM, Metz University), have been compared by Irstea (presented by V. Andréassian) with the participation of each team. Tests using daily data series will be run on 24 river basins, including two on the island Reunion, over identical periods (1974-1991 and 1992-2009 in continental France). The database has been set up and the assessment protocol drafted. The initial test results this year will enable the researchers to better identify the specificities of each model as well as the respective strengths and weaknesses. The long-term goal would be to have an operational, on-line tool providing forecasts with the hydrological survey bulletins.

Finally, climate change makes it necessary to link the economic and environmental impacts of low-flow conditions with the impacts of changes in river thermal regimes. The need for spatialised monitoring data on water temperatures led to the creation of the national temperature network (RNT) by Onema in 2008. An analysis of the data was assigned to Tours University (presented by F. Moatar). The work, slowed until now by the insufficient availability of RNT data, will be pursued in 2012 and 2013 in order to make progress in physically based modelling of the processes determining water temperature.

Groundwater/river interface at the source of the Riedbrunnen (Alsace).

Impact of climate change on groundwater and links with surface hydrology

To date, once anthropogenic influences and the specific kinetics of water tables are taken into account, it has not been possible to directly attribute significant trends in water-table levels in continental France to climate change. That is the result of the data analysed in 2010 by BRGM at the request of Onema, during a preparatory exercise to set up a piezometric reference network to monitor the impact of climate change on groundwater. The 377 piezometers, located for the most part in northern France and Alsace, were selected for the project because they are thought to be in areas only slightly influenced by human

activities. Only 37 piezometers registered significant trends lower and 26 registered significant trends higher.
However, there is no doubt that climate change will produce quantitative impacts in the years to come. The initial results of the «hydrogeology» part of the Explore 2070 project (presented by X. de Lacaze) foresee a drop in the recharge of the alluvial groundwater of the Rhine (approximately 5% by 2050) and that does not include the foreseeable increase in abstractions. Recharge of groundwater in the Seine basin will drop even more, 16% on average by 2050. Simultaneously, water infiltration from rivers to groundwater recharge should increase, which could in turn worsen the reduction of river average flow rates and the severity of low-flow conditions.
The study of groundwater/river interaction is thus more important than ever in support of water management. That is the goal of a three-year programme (presented by F. Paran, Armines) launched by Onema in 2011, in conjunction with the École des mines in Saint-Étienne, MinesParisTech, Irstea and BRGM. The programme, called Naprom, is now developing a multi-method approach to better understand groundwater/river interaction on five, very different sites, the Orgeval river near Coulommiers, the Sèvre Niortaise river at Échiré, the Écozone in the Forez region, the Rhône river between Donzère and Mondragon, and finally, the alluvial plains of the Rhine and the Ill rivers. Each basin was subjected to geomatic analysis and the researchers developed and implemented various approaches and metrics, depending on the configuration, e.g. subterranean invertebrates and macrophytes, temperature and pressure monitoring, geochemical analysis, isotopes, hydrological modelling of the basin, etc. In the beginning of 2015, the final report will produce a methodological guide on how to characterise quantitative exchanges between rivers and different types of aquifers.

Take full advantage of the monitoring networks

Many research projects in the field of hydrology, including modelling, depend on the availability and the quality of field data, but the high costs of hydrology and rainfall-measurement networks mean that difficult choices must occasionally be made. A project launched by Irstea (Ph.D. topic of L. Lebecherel), at the request of Onema, will attempt to evaluate the uncertainty caused by the effects of network densities. The evaluation is based on estimates of physical variables (QMNA5, estimated hydrographs, etc.) that are calculated for real river basins. This work will produce the data required to preserve and perhaps even expand the existing networks. In the meantime, it is more than ever necessary to take full advantage of the monitoring networks. Again at the request of Onema, a project at Irstea is now developing a method to reconstitute hydrological data series that are incomplete or missing using rainfall-runoff and runoff-runoff models. Another finished project (presented by C. Catalogne) proposed a mathematical method to use sporadic gauging data for QMNA5 estimates. The method extrapolates the missing data using the reference specific-discharge data series that best correlates with the limited gauging data, from among the 50 data series that are the closest geographically and react similarly to weather events. The study determined the uncertainties of the method and showed that it produces very clear improvements in estimates for measurement stations carrying out at least 20 measurements per year. In addition, the required number of annual measurements drops with the number of years that the station is in operation. These results will assist in devising strategies for discrete measurements to improve local knowledge of low-flow rates.

All of these projects, whether finished, in progress or just starting, provide an incomplete view of the scientific work undertaken in France to make operational progress in the linked fields of climate change and low-flow conditions. This work must be pursued and increased because it will produce the tools required by water managers to meet the future challenges of quantitative hydrology.

Caroline Henry de Villeneuve,
Rhône-Alpes regional environmental agency

Maintaining the measurement networks over time

«The research presented during this symposium lies at the heart of water-management issues. A project such as Premhyce will assist in anticipating low-flow conditions and constitute a major tool for water managers. It will be possible to limit consumption earlier and better adjust volumes. However, as is always the case for models, the level of performance depends on the quality of the data fed into the model and data quality is still insufficient. In the Rhône-Mediterranean region, which comprises a large number of small basins operating under diverse conditions (that is certainly the case elsewhere too!), we are dealing with the insufficient reliability of the «thermometer», due to breaks in data series, drift in measurements, etc. If we are to succeed in adapting to the new conditions, we must maintain our networks over time and make them more reliable, particularly in areas confronted with severe low-flow conditions.»

Meeting organisation

Pascal Maugis, scientific officer for quantitative hydrology at the Research and development department.

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Publisher: Patrick Lavarde
Coordination: Véronique Barre, Research and development department, and Claire Roussel, Information and communication department
Author: Laurent Basilico and Pascal Maugis
Translation: Cabinet Bartsch (info@bartsch.fr)
Editorial secretary: Béatrice Gentil
Layout design: Eclats Graphiques
Production: Accord Valmy
Printed on paper from sustainably managed forests by Panoply
Onema - 5 Square Félix Nadar - 94300 Vincennes
Document available at: http://www.onema.fr/ IIMG/EV/cat7a-thematic-issues.html#meetings